Wildfires and Earth-Surface Processes

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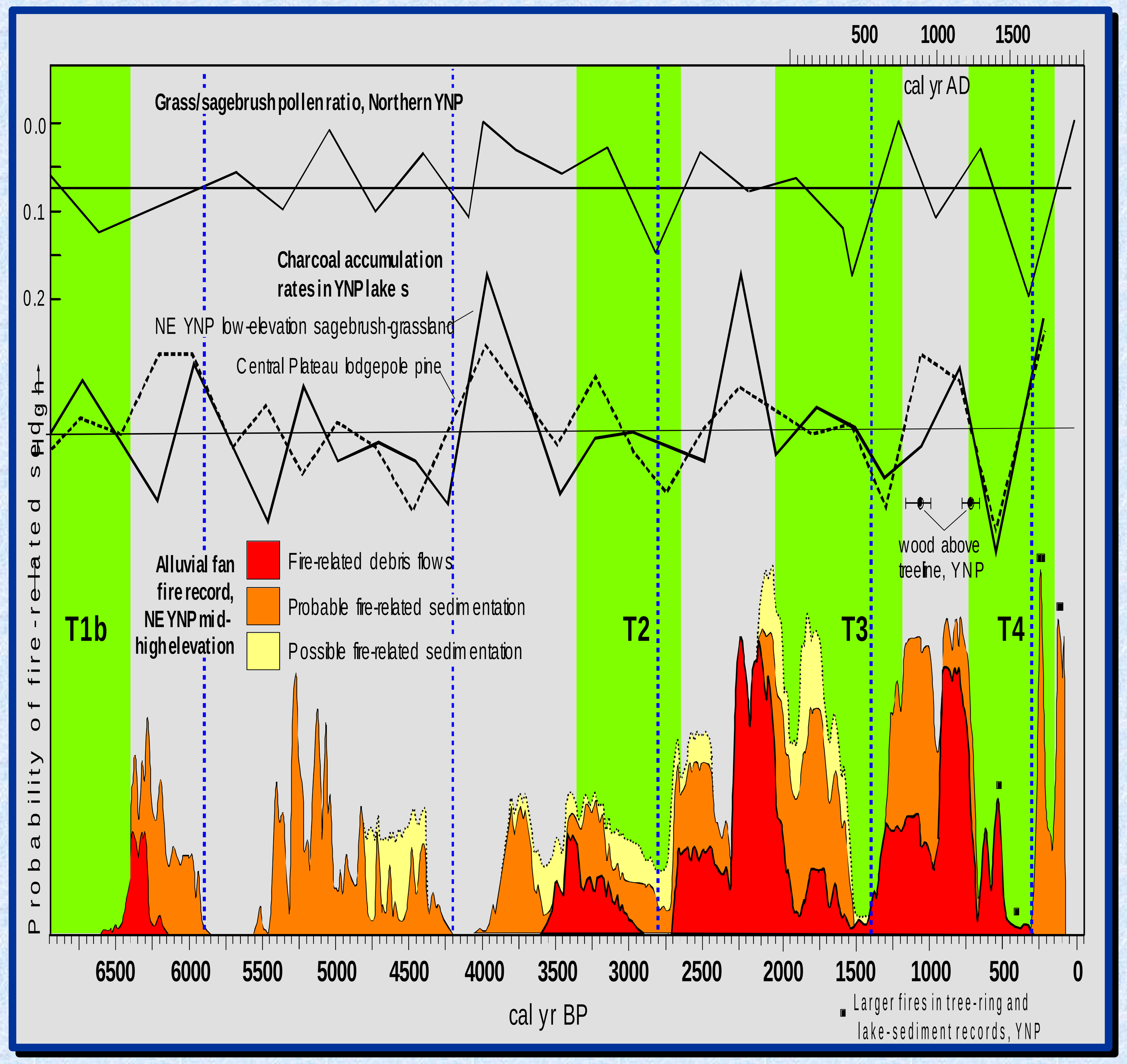
Fire-related 1989 debris flow deposit and high mudline on tree. Slough Creek, Yellowstone National Park. Photo from Grant Meyer.

Fire-related debris flow, Slough Creek. New surface provides potential sites for invasive species. Photo by Grant Meyer.

The area of northeastern Yellowstone National Park has been shown to have a strong positive relation between forest fires and debris flows onto alluvial fans during the last 6,000 years. Intervals of fire-related debris flows cause buildup of debris fans outward into the axial valley, whereas intervals with few fires result in axial streams trimming back the debris fans to form wider flood plains that are later incised to form terraces (Meyer and others, 1995, GSA Bulletin, p. 1211-1230). This area in northeastern Yellowstone has several geologic characteristics that enhance fire and fire-related sedimentation: (1) steep, long slopes associated with deep, young, incision, (2) extensive Pleistocene glaciation that has resulted in steep valley walls, and (3) readily erodible Absaroka volcanic rock with sufficient fines (silt and clay, as well as soils with a thin loess cap) to produce debris flows.

Rilled sloped after 1989 thunderstorm, Madison Canyon, Yellowstone National Park. Grant Meyer photo.



Chronology of mid-late Holocene fire-related sedimentation and fluvial terrace tread development (T2, etc.) compared to local paleoclimatic indicators (from Meyer et al., 1995).

1989 Debris flow that buried road along Gibbon River Canyon, Yellowstone National Park.

In contrast to this steep, Absaroka volcanic terrain with a significant amount of fine sediment, central Yellowstone is underlain by rhyolite that has much gentler slopes and forms sandy, more permeable soils. After the 1988 fires, nevertheless, debris flows were generated on local steep slopes on this rhyolite terrain. A topsoil supplemented with loess and aerosolic dust may have enhanced runoff and generation of debris flows.

Pickup truck swept off highway by debris flow, Gibbon River Canyon area, Yellowstone National Park.

Deep channel erosion provided much of the sediment for the 1989 debris flow, Gibbon River area, Yellowstone National Park.

Provided by Gallatin National Forest.

To understand and predict the extent of the hazard, geologic factors and consequent effects of fire on earth-surface processes need to be known and evaluated and include the following three factors. (1) Relation between geologic terrain and floods and debris flows, particularly fine-grained, relatively impermeable bedrock and surficial materials. For example, the Beaver Creek fire north of Hebgen Lake, MT, burned an extensive high-altitude area underlain by fine-grained, shaley rocks that are prime candidates to produce debris flows under intense rainfall such as that in the same area on July 18, 2000. (2) Steep slopes are more likely to erode or fail, and steep, long slopes have greater overland flow, thus resulting in soil erosion, and debris flows. (3) Fine-grained, impermeable material is most likely to be entrained in overland flow and aid in initiation of gully erosion to produce downstream flooding and debris flows. Topsoil in many western areas consists of wind-blown silt that once eroded will not be replenished until another ice age generates more silt.

Cabin Creek Trench, Hebgen Earthquake fault, Montana. Debris flows constitute most of the deposits exposed in the trench.

Earth-surface processes include the integration of both geologic and life processes at and near the surface of the earth. Fires and their aftermath integrate these biotic and abiotic processes, and have been part of ongoing earth-surface processes for millions of years.

In addition to their effect on vegetation, wildfires commonly result in floods and debris flows that erode upland slopes, erode channelways, and deposit material lower along drainages. These processes are hazardous to people, buildings, roads, and bridges. The extensive western fires of the summer of 2000 are likely to result in continued hardship for people in the burned areas as well as downstream floods and debris flows. Loss of vegetation in the burned areas results in increased runoff, soil mobilization by processes such as rain splash and loss of soil strength. Intense rainfall, particularly late in snowmelt when soils are saturated, can produce disastrous floods and debris flows.

We need to study the areas burned in the summer of 2,000 that have contrasting geology, terrain; and fire-severity to determine how the character of debris flows and floods produced by severe precipitation events relates to these different geologic terrains.

In addition, differing geologic terrains determine how fires burn and hazards created after they burn. (1) Some substrates hold lesser amounts of soil moisture and reach the wilt point much earlier, making them susceptible to more intense, rapid burning and post-fire erosion. (2) Geomorphic histories of landscapes produce terrain with different fire potential. For example, uplift and erosion of the eastern Greater Yellowstone Area have produced deeply incised terrain with high, steep valley walls capable of rapidly burning.

Soda Butte Creek in northeastern Yellowstone National Park. Erosion of the Tertiary volcanic material has produced a variety of slope steepness and orientation

Topography and wind combine to advance the fire. Fire brands falling from the smoke column in these situations can start spot fires more than a mile in advance of the fire front. Photo by West Yellowstone Smoke Jumpers.

Fires burn more vigorously up-slope and with the wind creating differences in fire severity and extent. Photo by West Yellowstone Smoke Jumpers.

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